Maturation Of Instruments For Solar System Exploration

A Planetary Broadband Seismometer for the Lunar Geophysical Network and the Ocean Worlds

Completed Technology Project (2017 - 2021)

Project Introduction

BACKGROUND AND RELEVANCE: The NRC decadal survey identified the Lunar Geophysical Network (LGN) as a high-yield New-Frontiers-class mission concept that will place a long-lived and globally distributed network of geophysical instruments on the surface of the Moon to understand the nature and evolution of the lunar interior from the crust to the core. This will allow the examination of the initial stages of planetary differentiation frozen in time some ~3-3.5 billion years ago. The objectives of LGN hinge on the capabilities of an ultra-sensitive, very broad-band (VBB) seismometer. LGN's objectives are designed to discover the interior structure and composition of the Moon that was not possible with the Apollo network. To meet these objectives, a VBB seismometer ~10 times more sensitive than the state of the art (SOA) is required while maintaining the sensitivity over a wide temperature range. Operating in high-radiation cryogenic environments will also benefit future exploration of Ocean Worlds. Ultra-sensitive seismometers are critical for detecting faint motions deep within the planet that can be used to reconstruct its interior while shedding light on fundamental processes such as plate tectonics, volcanism, ocean waves, ice flow, and geysering. TECHNOLOGY: The key PBBS technology is the Electrostatic Frequency Reduction (EFR) technique invented by Co-I Paik in which the mass-suspension natural frequency f0 is reduced to near zero by applying an electrostatic force. This technique broadens the seismometer's response, dramatically increases its sensitivity, and allows remote and fine adjustment of f0 to a level of precision not achievable otherwise. The ability to remotely and autonomously tune f0 is particularly important to operations in cryogenic environments, which cause suspensions to stiffen and result in an increase in f0 and a degradation in the low-frequency sensitivity. The University of Maryland (UM) and JPL have developed a proof-of-concept Planetary Broad Band Seismometer (PBBS) using EFR (TRL 3). The development was funded through the Planetary Instrument Definition and Development Program, and delivered a proof-of-concept sensor with comparable performance to SOA terrestrial seismometers. OBJECTIVES AND METHODOLOGY 1: Validate the PBBS performance for the LGN in relevant environment. (TRL 5) 2: Validate the PBBS performance in relevant environment of candidate Ocean Worlds. (TRL 5) The innovations that make these objectives achievable are: (1) The use of the EFR technology to provide very low resonance frequency, and to compensate for changes in the spring constant with temperature; (2) The use of specialized materials with tailored thermal properties for the springs and the housing; (3) The adaptation of sensitive displacement sensing techniques from the gravitational-wave detection community; (4) The use of advanced digital and analog electronics, including synchronous detection to eliminate 1/f noise that limits the low frequency performance of the InSight seismometer and a force-feedback loop implemented in software and encoded in a Digital Signal Processor (DSP) to allow automatic gain change in the event of a large quake; (5) The use of a commercially available cryogenic motor system for fine leveling and centering of the test mass; (6) The implementation of SOA electronic system; and (7)

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Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Responsible Program:

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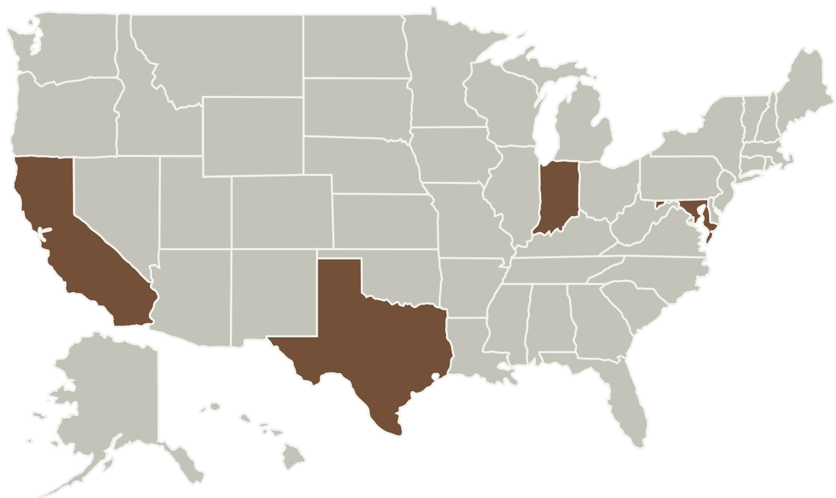
The use of low-thermal-drift components together with thermal compensation/correction. The technology advancement methodology is to isolate and track the performance of each subsystem, measuring and improving its performance separately and progressively as an integrated system, first in a laboratory environment and then in cryogenic conditions. A key aspect of this approach is the simultaneous achievement of the mechanical performance requirements in separate biaxial-horizontal and vertical configurations before integrating them into a single mass triaxial system in the fourth year.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
California Institute of Technology(CalTech)	Supporting Organization	Academia	Pasadena, California

Primary U.S. Work Locations	
California	Indiana
Maryland	Texas

Project Management

Program Director:

Carolyn R Mercer

Program Manager:

Haris Riris

Principal Investigator:

Talso C Chui

Co-Investigators:

Clive R Neal
William B Banerdt
Karen R Piggee
Nicholas Schmerr
Paul R Williamson
Ho Jung Paik
Steve Vance
Inseob Hahn
Sharon Kedar

Technology Areas

Primary:

- TX08 Sensors and Instruments
  └ TX08.1 Remote Sensing Instruments/Sensors
    └ TX08.1.1 Detectors and Focal Planes

Target Destination

Others Inside the Solar System